Design and Interfacing of the Optical Assembly for Automated Analyzer

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Abstract: ***In the presented work, low cost design of automated bio-chemistry analyzer is suggested. The system is designed in a modular way and consists of: optical assembly, auto-sample, interfacing hardware and software unit. The same may be used in different variants like semi-automatic bio-chemistry analyzer, fully automatic bio-chemistry analyzer. An automated analyzer is a medical laboratory instrument designed to measure different chemicals and other characteristics in a number of blood samples quickly, with minimal human assistance. Blood samples are placed in a rack of test tubes. This rack is rotated through a stepper motor for positioning of blood sample through the measurement chamber of the analyzer. The purpose of the fully automated bio-chemistry analyzer is intended for the labs where heavy load of blood samples is estimate. The principal of operation of a bio-chemistry analyzer is based on Lamberts and Beer's law of photo-chemistry. The transmitted light coming out of a liquid contained in a transparent glass depends upon the concentration (C), thickness (T) and intensity of the incident light.***

Keywords: BCA→Bio-Chemistry Analyzer, OD → Optical Density

1. Introduction

Biochemistry analyzer is a pathological instrument intended for biochemistry tests of the blood samples this instrument is mainly suitable for the labs which have routinely heavy load of blood sample testing. This instrument is mainly used for quantitative measuring and analysing various chemical and biologic elements of urine, human blood and other body liquid like kidney function, liver function microelement and other electrolyte as well as hormone and microalbumen. Automatic biochemistry analyser can do sampling, mixing, wiping off interferer, heat preservation detecting, calculating etc all by itself and is more powerful for fast speed and high precision. The automatic biochemistry analyzer and has advantages of lower price, easy operation and so on. The automation in analyzer covers the following:

- Samples Handling System
- Reagents Handling System
- Sample Aspiration
- Washing of the Flow Cell
- Auto incubation of the samples at selected temperature
- Auto Filter and electronic gain selection according to the test requirement
- Quality Control (QC) Test Schedule

2. Related Works

The biochemistry analyzer has been widely used to quantitative measuring and analyzing various biologic and chemical elements of human body fluid in clinic. In this paper, a kind of semi-automated biochemistry analyzer based on C8051Fxxx single chip microcomputer is presented. The analyzer employed the photoelectric measurement method and the endpoint analyzing method as well as dynamic analyzing method and so on. The measured items are above 40 and more than 1000 results can be stored. Moreover, the analyzer can communicate with the personal computer by RS-232 interface. Compared with the same type other product, this analyzer has the advantages of small volume, high ratio of performance to price and easy operation [1].

Automatic biochemistry analyzer is a necessary instrument for clinical diagnostics. In this paper, a new scheme of concentrated control system for Automatic biochemistry analyzer based on FPGA (Field Programmable Gate Array) is put forward. As an important part of automatic biochemistry analyzer, motor control system is one of key parts. In the light of the problems of stepping motor in application, such as surge at low frequency, low torque at high frequency and bad frequency characteristic, the paper presents a kind of practical method of the constant flow chopping subdivision driving based on FPGA. This scheme solves oscillation of stepping motor, improves the control system of biochemistry analyzer instrument [2]

The growth in the volume of work in clinical laboratories has produced a shortage of technicians skilled in executing work of this nature. As a result of the increasing workload, a demand for means of accelerating and simplifying the process of biochemical analysis now exists. The design of the equipment to be described in this paper is therefore intended not only to accelerate the task of analysis, but to minimize the skill required of the operator. A bonus has been obtained in minimizing the effects of human error and thus in improving accuracy [3]

Clinical chemistry analyser is a high-performance microcontroller-based photometric biochemical analyser to measure various blood biochemical parameters such as blood glucose, urea, protein, bilirubin, and so forth, and also to measure and observe enzyme growth occurred while performing the other biochemical tests such as ALT (alkaline amino transferase), amylase, AST (aspartate amino transferase), and so forth. These tests are of great

significance in biochemistry and used for diagnostic purposes and classifying various disorders and diseases such as diabetes, liver malfunctioning, renal diseases, and so forth. An inexpensive clinical chemistry analyser developed by the authors is described in this paper. This is an open system in which any reagent kit available in the market can be used. The system is based on the principle of absorbance transmittance photometry. System design is based around 80C31 microcontroller with RAM, EPROM, and peripheral interface devices. The developed system incorporates light source, an optical module, interference filters of various wave lengths, peltier device for maintaining required temperature of the mixture in flow cell, peristaltic pump for sample aspiration, graphic LCD display for displaying blood parameters, patients test results and kinetic test graph, 40 columns mini thermal printer, and also 32-key keyboard for executing various functions. The lab tests conducted on the instrument include versatility of the analyzer, flexibility of the software, and treatment of sample. [4]

3. Basic Principle

The basic principle of the biochemistry analyzer is based on LAMBERT BEER LAW. This law relates absorption of light to properties of the medium through which it travels. The amount of light penetrating into the solution which is termed as transmittance, and is expressed as the ratio of intensity of the transmitted light I_t and intensity of the incident light beam I_i. According to the lamberts law absorbance is directly proportional to thickness of sample, and according to the beers law absorbance is proportional to concentration of the sample. The Lamberts Beer law combines these two laws and correlates the absorbance to both concentrations as well as to the thickness (path length of sample).

Lamberts beers law is valid only for the diluted solutions. The limits for its validity differ for different solutions. In general we can say that every material showing absorption up to 0.5-0.6 obeys lamberts beer law.

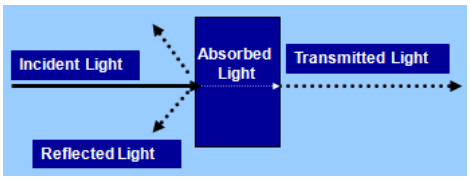

Figure1: Lamberts and beer law

A bundle of monochromatic light with intensity I_0 transmits through the sample solution with concentration C and arrives at the photoelectric converter. Suppose the transmitted light intensity is I, the distance that the light goes across or the light pathway is L, then

$I_0/I = e^{KLC,}$ where K is absorbency

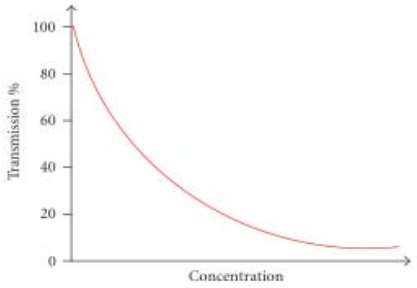

Figure 2: Relation between transmission and concentration

Thus it can be concluded that sample concentration can be measured based on relative change of the transmitted & incident light intensity provided if the light pathway is fixed. According to Lambert and Beer's law, when monochromatic light passes through colored solution, the intensity of the transmitted light decreases exponentially with the increase in concentration of the absorbing substance. The value of absorption of light energy is depends on the number of molecules present in absorbing material and the thickness of the medium. Thus, intensity of light energy leaving the absorbing substance is used to provide an indication of concentration of that particular substance. In this system, the basic requirement is to measure optical density/absorbance and the concentration of the test parameter under run accurately.

4. Block diagram

The basic block diagram of the fully automatic analyzer is shown in the fig.3 as shown below. The optical assembly for the system is constructed, which includes the halogen lamp, flow cell, the filter wheel assembly attached to the stepper motor that controls its movement, a photodiode and two pairs of the plano convex lenses that are placed so as to provide the proper focussed beam of the light to fall on the photodiode. The motion of the stepper motor is controlled by the AT89C51RE2 microcontroller. A filter is selected for the test to be carried out on the sample, and then the filter is brought in the front of the flow cell in which the sample is placed. Whenever a desired filter for a specific test is to be selected, the filter wheel is moved from its home position to the desired position. In this way the desired filter is selected.The movement of the filter wheel or the placement of the corresponding filter in front of the flow cell is controlled by a stepper motor which is programmed through the controller. The light generated from the halogen lamp passes through the sample placed in the flow cell and further passes through the filter. We have a module that is fitted with the lens so as to provide proper pathway to the light. The light then falls on the photodiode which converts the light into an output voltage. The photodiode is placed in between the signal conditioning unit and the controller.

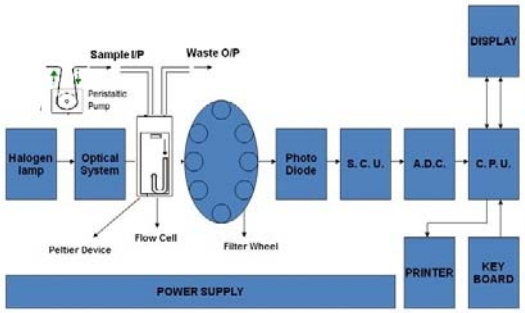

Figure 3: Block diagram

The voltage which is generated from the photodiode is of order few mill volts and is not sufficient to drive the further circuitry so we therefore have signal conditioning equipments. In our system hardware the signal conditioning unit primarily includes an amplifier, a second order low pass butterworth filter and a buffer. The amplifier boosts up the amplitude of the output voltage as generated by the photodiode. The second order butterworth filter is designed to remove the noise by increasing the signal to noise ratio and to do filtration in order to remove the unwanted signals. The butterworth filter is designed with a cut off frequency of about 5-6 KHz. The main aim of the buffer is to make the output impedance minimum. The flow chart of the working of the proposed system is given in fig.4 below.

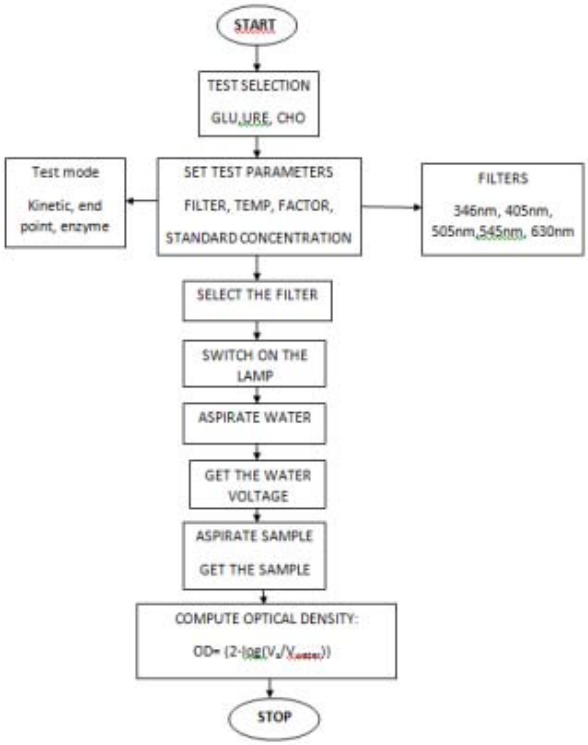

Figure 4: Flow Chart

5. Auto-Sampler Interface and Control

An auto-sampler system used in fully automatic bio-chemistry analyzer is an integral part of the instrument. The auto-sampler is an electro-mechanical device fitted with different probes to aspirate water, reagents and samples from the test placed in different holes provided in the sampler tray. Each test tube has its unique position and is programmed in the software section of the unit. The entire sampler unit is attached to stepper motor shaft and the position of each test tube is controlled via the commands from software section in synchronization with different probes. The probes are also attached on to a separate stepper motor shaft. Once a particular test is selected and respective test tube comes under the probe. The probe is moved down into the test tube to aspirate the water/sample or reagent. The sampler may have a number of test tube positions depending upon its application and requirement. The placement of test tube should be precise enough so that each test tube is at an equal angular distance from one another. This ensures the proper dipping of the probe into the selected test tube.

Figure 5: Reagent Sampler

6. Optical Assembly Interface and Control

The optical assembly for the system is constructed which includes the halogen lamp, flow cell, the filter wheel assembly attached to the stepper motor that controls its movement, a photodiode and two pairs of the plano convex lenses that are placed so as to provide the proper focussed beam of the light to fall on the photodiode. The movement of the stepper motor is controlled through the microcontroller AT89C51RE2.

Once the test to be carried out is selected then the corresponding filter in the filter wheel is brought in front of the flow cell and pair of plano convex lens.Optical module consists of a light source with reflector, condenser system, collimating objectives, flow cell, filter wheel assembly, and photodiode. Halogen lamp is used as a light source. A constant current power supply is used to power the lamp to reduce the fluctuations in the light. All optical components have been designed with quartz glass to have good transmission in UV region at 340nm.

Keeping in view the low response of photo detector in UV (340nm), all the optical components have been provided with enhanced antireflection coating in the UV region. In the opto-mechanical assembly, special care has been taken in the design so that each component is properly aligned with respect to optical axis. To get the required wavelength of light to be passed, 6 interference filters of different wavelengths such as 340nm, 405nm, 505nm, 546nm, 578nm, and 630nm, from UV region to visible region spectrum (300nm to 700nm), have been mounted on the filter wheel.
These filters are selected automatically depending on the test performed. When the filter of required wavelength is selected, the corresponding gain is selected automatically. The filter wheel is driven by a stepper motor, which is

interfaced with the port of microcontroller through driver circuit. Pulses are generated according to required sequence to rotate the motor at required angle, which brings the filter in front of photo detector.

Figure 6: Optical Assembly of the analyzer

7. Optical Density Computation

The optical density of the sample is given by:

Optical Density (OD) = 2 - $\log_{10}$(T), and T is Transmittance given by:

$T = I_t / I_0$

Where, I_t is intensity of transmitted light, and Io is the intensity of the incident light

T is also computed by the following equations:

Say, V_w and V_{sample} are the voltages with water and sample respectively.

Then T is given by:

$$T = (100 \times V_{sample} / V_w)$$

8. Results

Table 1: Filter = 340 nm

Sr. No.	V_w	V_{sample}	*T*	*OD*
1	1.3	1.31 V	100	0
2		0.5 V	38.46	0.41
3		0.3 V	23.07	0.63

Table 2: Filter = 405 nm

Sr. No.	V_w	V_{sample}	*T*	*OD*
1	1.5	1.52 V	100	0
2		1.22 V	81.33	0.08
3		1.31 V	87.33	0.05

Table 3: Filter = 505 nm

Sr. No.	V_w	V_{sample}	*T*	*OD*
1	1.84	1.83 V	100	0.01
2		1.52 V	82.60	0.08
3		1.34 V	72.82	0.13

Table 4: Filter = 546 nm

Sr. No.	V_w	V_{sample}	*T*	*OD*
1	1.76	1.78 V	100	0
2		1.52 V	86.36	0.06
3		1.30 V	73.86	0.13

Table 5: Filter = 578 nm

Sr. No.	V_w	V_{sample}	*T*	*OD*
1	1.90	1.98 V	100	0
2		1.52 V	80	0.09
3		1.38 V	72.63	0.13

Table 6: Filter = 630 nm

Sr. No.	V_w	V_{sample}	*T*	*OD*
1	2.13	2.16 V	100	0
2		1.55 V	72.76	0.13
3		1.93 V	90.61	0.04

9. Conclusion

A front end interfacing software is designed to check the performance of the presented system. The system works fine when loaded with 100 samples in the sampler tray positions and distilled water in a separate beaker kept outside the sampler position area. The average time of each test in end point mode is observed to be around 10-12 second. The speed is tested in ideal case i.e. when the mode is end point and same test is repeated and water and standard aspiration is done only once. Further the test time increases as the positions goes far from the home position. To optimize this lag time, the sampler arm is made home in the centre of the sampler so that half the tests positions are on left side and half on right side.

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